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Commutation device,
especially a commutator,
and method for producing such a device

This invention relates to a current reversal device, a commutator in particular, and to a process for production of such a device. Such devices are employed especially in electric motors and current generators, as for example in tools powered by electricity, actuating drives, or fuel pumps.

Generic devices in this category are disclosed, for example, in DE 41 37 400 C2. In this instance a composite segment is stamped from a rolled or drawn copper strip and then is roller burnished, split a short distance or scored, and sprayed with a compression molding compound which after setting forms the outer cover of the commutator. Then the bore in the outer cover must be machined and the clasps of the commutator segments bent for fastening the ends of the windings. After an additional scaling or stripping procedure the commutators undergo electrical testing and are then mounted on the engine shaft by force fitting.

In addition, DE 195 30 051 A1 discloses a plug-in commutator in which the commutator segments are inserted into an assembly cage and then sprayed with molded plastic material to form the outer cover. These operations are followed by additional machining and testing steps carried out to comply with the requirements set for accuracy of the geometric dimensions of the commutator and for the stability of the latter.

DE-OS-2 352 155 discloses a commutator for a miniature electric motor and a process for manufacture of this motor, in which a desired number of commutator plates are fastened on a jacket surface of a core in specific sectors by means of an adhesive.

State-of-the-art commutators require a large number of production and testing steps in order to make it possible to guarantee the required degrees of accuracy and reliability.

Hence it is the object of the invention to develop a commutator which exhibits high accuracy with respect to its geometric dimensions and high long-term stability and is also simple to manufacture.

The object is attained by means of the device and process disclosed in the independent claims. Special embodiments of the invention are disclosed in the subsidiary claims.

According to Claim 1, the segments may be fastened on the outer cover by fastening means mounted more or less between the outer cover and the segments. The outer cover is generally made from an electrically insulating material, in particular a plastic such as a duroplastic, a thermoplastic, or a ceramic material. Consideration may be given as an alternative also to a metal outer cover such as one of aluminum whose surface is provided with a preferably electrically insulating coating such as a coating of varnish or a layer of metal oxide which may also be produced by oxidation of the metal outer cover. The outer cover may also be built up in two or more layers, and especially may have a flexible internal hub surrounded by a temperature-stable outer shell on which the segments may be fastened. The flexible internal hub provides for the necessary force fitting for mounting the commutator on an engine shaft. The commutator segments generally consist of copper or a copper compound; consideration may be

given alternatively also to other materials in keeping with the requirements set for conductivity, temperature stability, and chemical resistance. The fastening means is preferably applied in layers between the segments and the outer cover and may be applied prior to fastening on the outer cover and/or the segments.

The outer cover and the segments have interacting means for positioning and orienting the segments relative to the outer cover. They may be made in the form of punctiform, linear, or planiform projections and matching recesses on the outer cover or on the segments. The segments, for example, may have studlike projections which may be inserted into matching grooves oriented parallel to the axis of rotation on the circumference of the outer cover. In the case of a planar commutator, radially oriented studs on a frontal surface may fit into corresponding recesses or grooves on the pertinent segment or the cylindrical outer cover may have on the edge on its front side an axially projecting and preferably circumferentially annular continuous projection which ensures centering of the disk segment to be fastened on the front surface, which disk segment may then be divided into individual commutator segments electrically insulated from each other.

If the fastening means is a layer of adhesive, this layer may be filled with suitable additives meeting electric and/or thermal requirements. The thermal coefficient of linear expansion of the adhesive layer, for example, can be reduced by a ceramic filler. If required, an electrically conductive metal filler, such as one based on Ag, Cu, or Ni may be used to establish a connection between the segment and the outer cover, for example, if the outer cover for a planar commutator comprises electrically conductive segmental connecting lines. The fillers may in particular define a distance between the commutator segments and the outer cover and so the

thickness of the adhesive layer, preferably by means of spherical fillers, especially ones in the form of glass or ceramic spheres. The layer thickness ranges, for example, from 20 to 250 μm and preferably from 50 to 100 μm. The layer thickness may also be determined in advance by means of spacers, preferably in one piece, made up of the outer cover or the commutator segments, as for example by punctate, linear, or planiform projections. The adhesive to be selected or treated is one such as will absorb as little moisture as possible after setting, one which will form a permanent strong bond with copper in particular and is dimensionally stable when subjected to mechanical and/or thermal stress.

If the fastener is a soldered or welded layer, the commutator possesses particularly high temperature stability and chemical resistance. Consideration is given in this case preferably to low melting soft, hard, or glass solders, such as low melting lead/tin solders or glass solders with a high lead oxide content. An especially low bonding temperature is obtained by ultrasound or friction welding.

If the segments and the outer cover have force fitted interacting anchor and receiving means, the segments may be inserted into the outer cover and the spring loaded anchor and receiving means operating in opposition to each other form a sufficiently stable clamp connection. In addition, the segments on the outer cover may be positioned by the bonding means. It is also possible, however, to dispense with an additional bonding agent and to position the segments exclusively with anchor and receiving means forming a clamp connection. Both the segments and the outer cover may have only anchor means or only receiving means or a combination of anchor and receiving means. The sole essential requirement is that anchor or

receiving means of the segment interact with receiving or anchor means of the outer cover.

It is especially advantageous for it to be possible to insert or clip the segments radially into the outer cover, as for example in the case of a drum commutator, or to insert them axially into a frontal surface of the outer cover, in the case of a planar commutator, for example.

It is also advantageous for positioning and orienting of the segments to take place simultaneously with insertion of the segments into the outer cover by means of the anchor or receiving means. Means for positioning and orienting extend preferably parallel to the axis of rotation along a peripheral surface or radially to the axis of rotation along a frontal surface of the outer cover. All suitable configurations, in particular studs which are triangular, rectangular, hemispherical, or swallow-tailed in cross-section, may be considered as positioning and orienting means. Cross-sectional shapes which widen out in depth, and especially ones provided with a point for ease of insertion, are particularly well suited for anchoring.

In the process claimed for the invention segments are fastened to the outer cover by means of a bonding agent mounted more or less between the outer cover and the segments. For example, the outer cover as a whole may be immersed in a bonding means bath before the segments are fastened. Alternatively or in addition, at least the surface of the segments facing the outer cover may be provided with the bonding means. Optionally the surfaces of the outer cover and/or of the segments are to be cleaned and/or provided with a bonding agent before the fastener is applied. The surfaces may by preference be conditioned in a vacuum process, such as in an ion or plasma vacuum process. Surface treatment may also be carried out to achieve

adequate aging and corrosion resistance of the fastening layer to stresses during subsequent use and/or uniform wetting means with the fastener. Secondary treatment of the bonded joint is also advantageous in cementing in particular in order to prevent corrosion and/or infiltration and so reduction of the strength of the fastening.

Means for positioning and orienting the segments are provided whose shape is such that positioning and orienting take place automatically as the segments are delivered, for example grooves triangular in cross-section in the outer cover, into which studs of the segments of matching cross-section are introduced. In this case the fastening means may be introduced into the groove, for example, as a line of adhesive, before delivery. As the segments are subsequently delivered the fastening means is displaced to form a flat bonding layer between outer cover and segment.

If a clamp connection is established between anchor and receiving means, fastening means introduced between the outer cover and the segments may be dispensed with. In this instance fastening is effected exclusively by means of anchor and receiving means forming part of a clamp connection.

If fastening means is provided, an adhesive, solder, or weld layer is to be considered in particular for this purpose. The maximum temperature in additional treatment may be around 300 °C for a brief period. Setting of an adhesive layer should always take place at the lowest possible temperature, for example, in the temperature range from 50 to 250 °C, preferably from 170 to 200 °C.

If segments are delivered to the outer cover sequentially, this may be effected by step-by-step rotation of the outer cover around its axis of rotation and application of the segments piece by piece or by

rolling of the outer cover onto the segments interconnected in a strip, for example. In the case of step-by-step delivery the connection between the outer cover and the pertinent segment may be established either immediately after delivery or as the final step for all segments delivered together, for example, by surrounding the outer cover with segments in place with compression and/or heating tongs.

If all segments are delivered to the outer cover simultaneously, this may be accomplished with a suitable compression and/or heating tool, which following delivery ensures mechanically reliable fastening of the segments to the outer cover. It may be effected, for example, by pressing the segments into the outer cover, in particular by pressing the anchor and receiving means together and/or by heating the segments to the point of melting of the fastening means and production of a bonding layer.

Additional advantages, features, and details of the invention are to be found in the subsidiary claims and in the following description, in which several embodiments are described in detail with reference to the drawings. Each of the features referred to in the claims and in the description is an essential element of the invention, either individually or in any combination.

Figure 1 presents a cutaway side view of the commutator claimed for the invention,

Figure 2 various embodiments of the positioning means over section II-II in Figure 1,

Figure 3 a section through a planar commutator parallel to the axis of rotation,

Figure 4 a sectional view of an alternative embodiment of a planar commutator,

Figure 5 a view of the frontal surface of the planar commutator in Figure 3,

Figure 6 a blanked out flat commutator segment,

Figure 7 a possible method of assembly of the segment in Figure 6, and

Figure 8 the production process illustrated by a flow chart.

Figure 1 presents a side view of a cutaway commutator 1 as claimed for the invention. The more or less cylindrical outer cover 3 having an axis of rotation 2 consists preferably of a thermoplastic or duroplastic, such as a hollow cylinder of phenol resin produced by hot casting. Electrically insulated from each other over the circumference on the cylindrical outer wall and preferably containing copper or a copper compound are segments 4, whose ends are bent to form a hook for connection of the accompanying coil winding (not shown). The segments 4 are secured by fastening means 5 mounted more or less between them and the outer cover 3, in this instance by an adhesive layer of epoxy resin, polyurethane resin, or phenol resin. Shown in the lower half of Figure 1 is a second commutator segment 4′ having two anchor means 4" oriented radially as one piece; it both increases the stability of fastening of the second segment 4′ on the outer cover 3 and simultaneously performs the function of positioning and orienting the second segment 4′. The anchor means 4" engages corresponding recesses in the outer cover, which may be in the form, for example, of circumferential annular grooves 3′ or circumferential annular shoulders 3". Fitted on the outer cover 3 is a cone 15 which

simplifies sliding of the outer cover 3 onto an engine shaft (not shown).

Figure 2 shows various embodiments of means for positioning, orienting, and anchoring segments 4 on the outer cover over section II-II in Figure 1. In figure section 2A segment 4a has two studs 4a' triangular in cross-section and extending parallel to the axis of rotation 2 (perpendicular to the plane of the drawing); these studs are either pressed into the outer cover 3 by application of force and/or under the influence of temperature or are inserted into suitably shaped grooves in the outer cover 3. Figure Section 2B shows a segment 4b with a single central stud 4b' also triangular in cross-section and extending parallel to the axis of rotation 2. Figure section 2C shows a segment 4c with an anchor element 4c' which initially extends as a stud and has on its end oriented toward the axis of rotation a thickened area more or less circular in cross-section. The anchor means 4c' may extend parallel to the axis of rotation 2 in the form of a stud over a part or over the entire axial length of the outer cover 3 or may be punctate, in the form of a mushroom, for example. In either case, the anchor means 4c' fits into a corresponding recess in the outer cover 3, which is elastically deformed in this area and applies a clamping force ensuring stable fastening of segment 4c. Figure section 2D with segment 4d and anchor means 4d' and figure section 2E with segment 4e and anchor means 4e', swallow-tailed in cross-section, show another two of the anchor means, which may be in virtually any configuration desired. Anchor means 4f' in figure section 2F, preferably forming a single piece with segment 4f, is configured from the viewpoint of geometry and material so that it is deformed initially when segment 4f is pressed into the outer cover 3 and when fully inserted fits into a more or less T-shaped recess in the outer cover 3. In this embodiment as well elastic deformation of the outer cover takes place in the area engaged; such

deformation applies the clamping force required for segment 4f. Figure section 2G shows a segment 4g bent radially on its longitudinal sides or suitably shaped, the two sides 4g' either fitting into corresponding recesses in the outer cover 3 or cutting into them as a result of application of force. Figure section 2H shows a segment 4h with a cross-section in the form of a circular segment, the segment being inserted into a corresponding recess in the outer cover 3. Figure sections 2A to 2H show only a selection of the large number of the positioning, orienting, and anchoring options for the segments 4 on the outer cover 3. The anchor means on the outer cover 3 and corresponding recesses or receiving means in the segments may, of course, be analogously shaped. In addition or as an alternative to the anchor means, fastening may also be effected by a bonding layer, such as an adhesive, solder, or weld layer.

Figure 3 shows a section through a planar commutator 101, with an outer cover 103 having an axis of rotation 102, which also comprises electric connection means 103′ provided for connection of the coil windings which are to establish contact with segments 104 fastened on the frontal surface of the outer cover 103. If the outer cover 103 consists of an electrically insulating material, the connection between the outer cover 103 and the electric connection means 103′ may be made in the form both of an electrically insulating and an electrically conducting bonding layer 103", such as an adhesive, solder, or welded layer. On the other hand, the connection 105 between electric connecting means 103′ and segments 104 is to be established in all cases by means of an electrically conductive bonding layer 105, as for example by means of an adhesive layer filled with metal particles. The electric connection means 103′ may initially be in the form of a copper cup spray coated preferably with a duroplastic to form the outer cover 103. Circular segment disk 104, preferably consisting of carbon or containing carbon, is fastened on

outer cover 103 as thus preformed by means of bonding layer 105. Electric insulation of the commutator segments is then effected by means of cuts through the segment disk which are radial relative to the axis of rotation 102 through segment disk 104 and through the frontal bottom surface of the copper cup of connecting means 103′.

Figure 4 illustrates another planar commutator 201 with an axis of rotation 202 and a bar-shaped connection means 203′ which is a component of the outer cover 203. The bonding layer 205 between connection means 203′ and carbon disk 204 is electrically conductive. The bonding layer 203" between connection means 203′ and the outer cover 203 may be either electrically insulating or electrically conductive. An alternative embodiment of a copper planar commutator in which the copper planar segments 403′ are fastened to an electrically insulating or electrically conductive adhesive layer 403" on the outer cover 403 is illustrated in the lower half of Figure 4.

Figure 5 presents a view of the frontal surface of the planar commutator over section V-V in Figure 3 with carbon disk 104 not yet fastened. In a segment area 103a there is provided in a bottom surface of the cupshaped connection means 103′ a recess 106 shaped as a keyhole into which a matching pin-shaped or stud-shaped projection 107 of a preformed outer cover core may be inserted. In this way the connection means 103′ may be fastened on the preformed outer cover core as an addition or as an alternative to bonding layer 103", in order to exert a clamping effect.

Figure 6 shows a punched out flat segment 304 of copper for a drum-type commutator which consists essentially of a rectangular segmental surface 308 proper from a narrow side of which project two external positioning and orienting means 309 and a central stud 310, the latter being provided for connection of the coil winding. A

positioning means 311 is also formed on the opposite narrow side. Each of positioning means 309, 311 has a projecting lug on its end. After the segment 304 has been provided with curvature matching that of the outer cover, the positioning means 309, 311 are bent to an angle of approximately 90° relative to segmental surface 308 in the direction of the arrow 312, as illustrated in Figure 7. The bent positioning means 309, 311 are introduced into corresponding receiving means in the outer cover 303 and are thereby positioned and oriented. Segment 304 may be fastened on outer cover 303 exclusively by clamping between positioning means 309, 311 and the outer cover 303, or alternatively or additionally by a bonding layer 305. The outer cover 303 consists for this purpose exclusively of a flexible core 314 which exerts a flexible clamping effect on segments 304 or positioning means 309, 311 and force fitting on the engine shaft (not shown). Externally the outer cover 304 has an outer shell 315 which extends radially relative to the axis of rotation 302 and is form and temperature stable. The right half of Figure 7 illustrates an alternative option of bending the positioning means 309, in which repeated bending forms a clasp 309′ which is inserted into a matching recess in core 314; similarly (by a process not shown) the positioning means 311 on the opposite side may be inserted as a clasp.

A flow chart illustrating the production process is presented in Figure 8. Shaping of the outer cover and of the pertinent segments proceeds in parallel; both the outer cover and the segments are preferably cleaned with suitable solvents or cleaning agents before being placed in position, and if necessary a bonding agent is applied. Positioning of the segments on the outer cover may be carried out sequentially or simultaneously; in any event during the delivery the segments are oriented and positioned relative to the outer cover. Lastly, the segments are fastened on the outer cover by clamping,

adhesion, soldering, or welding. Adhesion, soldering, or welding may be provided as an alternative or supplement to clamping.